Large Aperture, Scanning, L-Band SAR

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***Abstract* — We have developed the first L-band membrane-based active phased array. The antenna is a 16x16 element patch array with dimensions of 2.3mx2.6m. The array uses membrane-compatible Transmit/Receive (T/R) modules for electronic beam steering. We will discuss the antenna design, the fabrication of this large array, the T/R module development, the signal distribution approach and the measured results of the array.**

I. Introduction

Future Earth Science and defense related phased array radar missions require electronically steerable, large-aperture antennas in Geosynchronous, Medium and Low Earth Orbits (GEO, MEO or LEO) [1-5]. Steerable, lightweight phased arrays also have application in lunar and planetary missions for topography of the Moon and other planets. Conventional phased-array antenna technologies with a mass density of 8-15kg/m^2 (for antenna, electronics and structure) will not meet the goals of these future space-based Synthetic Aperture Radar (SAR) missions due to their large mass, stow volume and cost. Current systems use rigid manifolds where electronic components are individually packaged and integrated onto panels. In order to realize very large aperture (>200m^2) spaceborne radar missions, ultra-lightweight active phased-array antennas are required. One promising method of dramatically reducing the weight, volume and associated cost of space-based radar is to replace the conventional large manifold antenna architecture with a flexible thin-film membrane antenna, such as JPL's membrane patch-antenna [6, 7]. This revolutionary antenna concept has been successfully demonstrated as a passive array antenna. The next step to increase performance of the membrane antenna is to demonstrate an active array. This requires a membrane-compatible Transmit/Receive (T/R) module to achieve fully active phased-array capability. We have been working on developing new architectures and technologies related to large active arrays and the integration of T/R modules with flexible membrane antennas.

In our previous tasks funded by Earth Science Technology Office (ESTO) we developed a 2x4 element active array [7] and an 8x16 passive array [8]. This work is an expansion on the previous work and addresses the issues related to developing a large active membrane array.

II. Membrane Array Architecture

The antenna consists of two separate membrane layers. See Fig. 1 for unit cell detail. One membrane (Layer 1) has the active Transmit/Receive (T/R) electronics (Layer 1, side A) and the RF and DC distribution networks (Layer 1, sides A and B connected through vias) as well as the ground plane (Layer 1, side B). The second membrane (Layer 2) has bare dielectric on side A and the radiating patches on side B. A slot etched in the Layer 1 ground plane feeds the patch antenna in Layer 2, with no physical connection between the layers [9]. A microstrip connected to the T/R module in side A feeds the signal to the slot in side B.

Although the application requires one Transmit/Receive module per element, for cost-saving purposes, in this demonstration we used a sparse array with one T/R module per 4 patch elements. Fig. 2 shows a collapsed view of our 16x16 array, with the critical elements on all layers combined into a single view. The antenna consists of 16 individual 2x8 arrays that are seamed together. Each 2x8 section includes etched copper lines for the DC, Control and

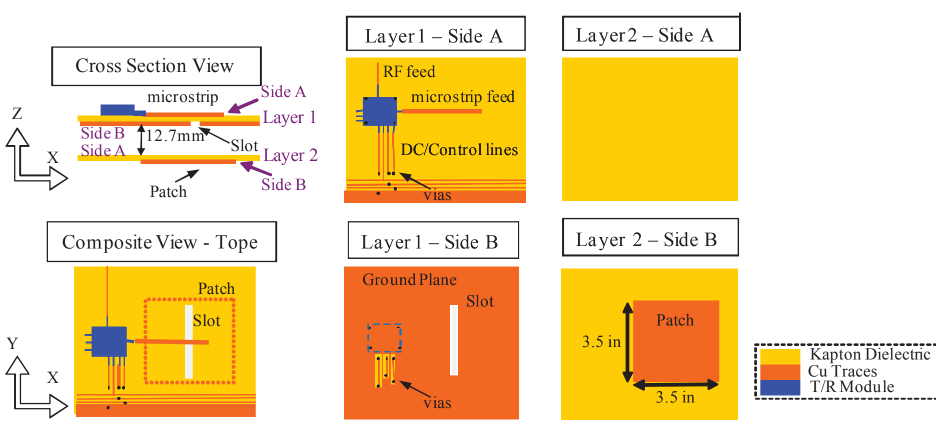

Figure 1. Membrane radar unit cell detail.

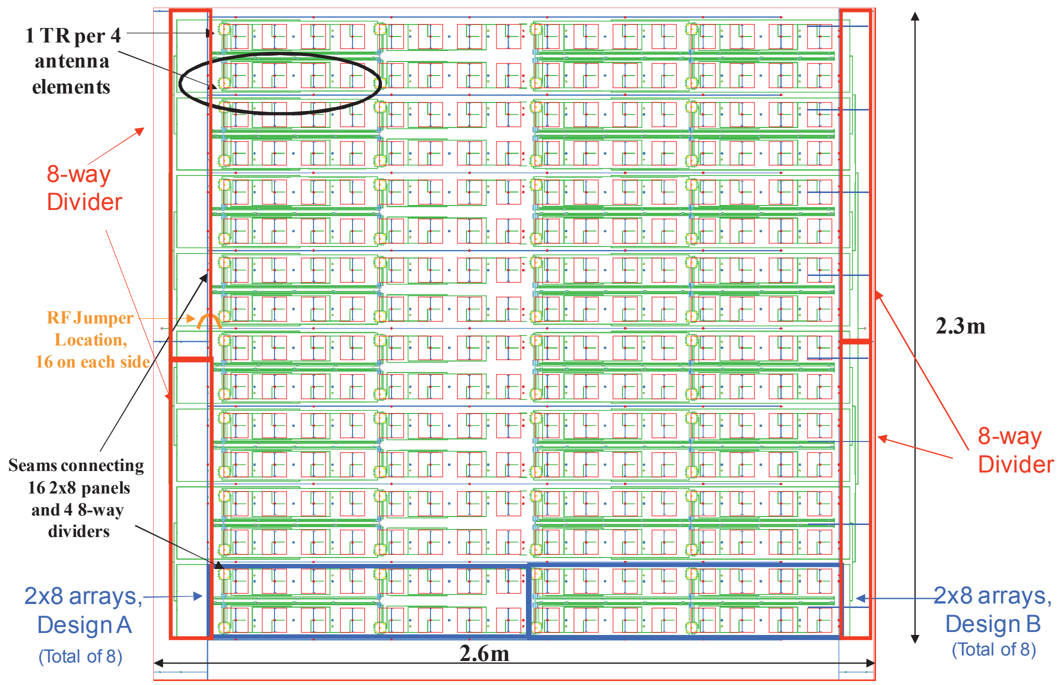

Figure 2. Collapsed view of the16x16 element sparse array with 1 TR for 4 elements. Location of one jumper is shown.

RF distribution that feed the T/R modules and the antenna elements in that panel. For this demo we used 16-way dividers (consisting of 2 segments of 8-way dividers) on the right and left-hand-side of the array for RF signal distribution. The use of the divider is only practical for this demonstration because for larger arrays the 16-way divider introduces a gap in the array that will create grating lobes (unwanted sidelobes) in the antenna pattern. For larger antennas required for our MEO application we need to develop a compact and integrated power divider.

We also developed a seaming technique to create a large array from smaller panels. These seams are necessary because handling, etching and processing an entire 10mx40m antenna (expected size of a MEO SAR) is impossible and the material not available. We developed and evaluated a seaming method that provides sufficient mechanical strength and minimizes misalignment. The antenna design requires that each patch on the antenna be aligned with its corresponding feed within a tolerance of 2.54 mm from the nominal. Since the antenna serves as a substrate, including RF traces (layer 1, sides A and B of Figure 1) and RF grounding (layer 1, side B of Figure 1) it is also necessary to provide electrical continuity of the ground plane and continuity of the RF traces. To achieve the required ground plane continuity, we used a combination of various Kapton tapes as well as conductive and non-conductive epoxies for the seams. The details of the seaming technique are discussed in [8]. Figure 3 shows the 16x16 element array and Figure 4 is a close-up of this array. The seams are visible in Fig. 4. We used (61cmx127cm) DuPont™ Pyralux® AP panels for this antenna. We also developed a technique for feeding RF signals from one panel to the next using RF jumpers while maintaining the proper line impedance, which is critical for RF signals. See Figure 2 for the location of one of these jumpers.

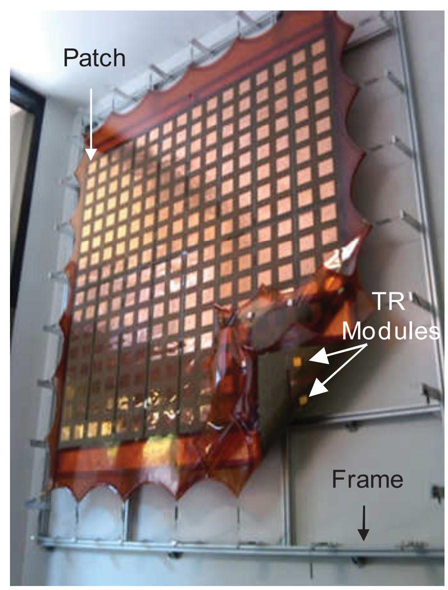

Figure 3: 16x16 element active membrane array. The 2 layers of the array are flipped to reveal 2 of the T/R modules that are mounted on Layer 1, side A (per notation in Fig. 1).

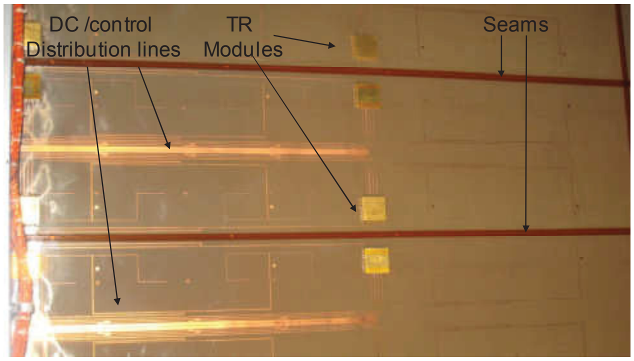

Figure 4: Close-up of the antenna (Layer 1, side A)

III. TRANSMIT/RECEIVE MODULE

The details of the T/R modules are discussed in [8]. Figure 5 shows the T/R module with its cover removed. Figures 3 and 4 show the covered T/Rs mounted on the antenna. To miniaturize the T/R module we used bare die for the RF portions of the module. The assembly challenge for this module is its hybrid, mixed technology construction where we assembled the bare die and packaged parts using the same process.

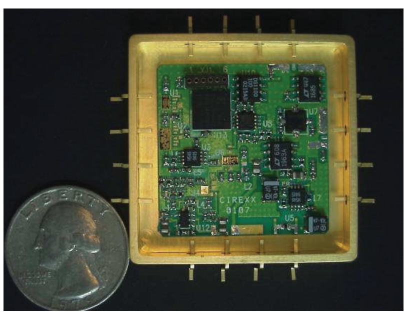

Figure 5: T/R module with its cover removed.

IV. MEASURED RESULTS

We tested this active phased array using a planar near field range at JPL. Figures 6, 7 and 8 show the calculated and measured E-plane transmit patterns at our center frequency of 1.26GHz as we scanned the beam. The scanning is achieved by adjusting the phase shifter value in the T/R modules. We achieved good results up to 30^o scan angle. Figures included here show results for scanning angles of 0^o, 10^o and 20^o. We also conducted measurements in receive mode and observed similar results. The receive mode plots are not shown. The near field scanner allowed us to check the health of each T/R module during testing. We noted that several of the T/R modules did not have the expected gain during these tests; they might have been damaged during the assembly of the array. The agreement between the measured and simulated results will further improve with 100% healthy T/Rs.

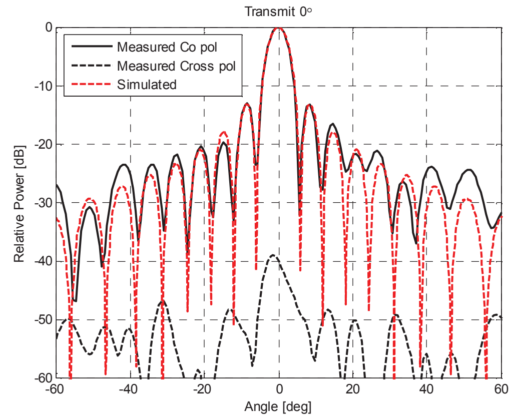

Figure 6: Antenna transmit patterns for 0^o steering angle.

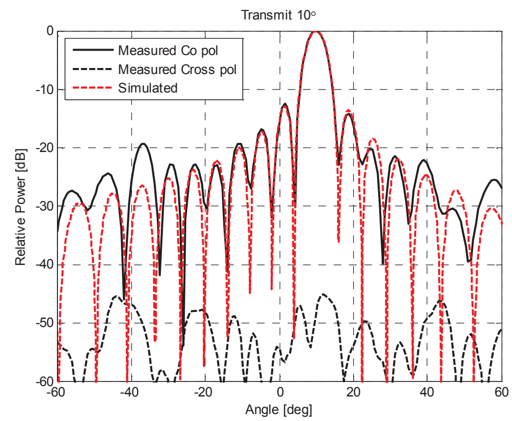

Figure 7: Antenna transmit patterns for 10^o steering angle.

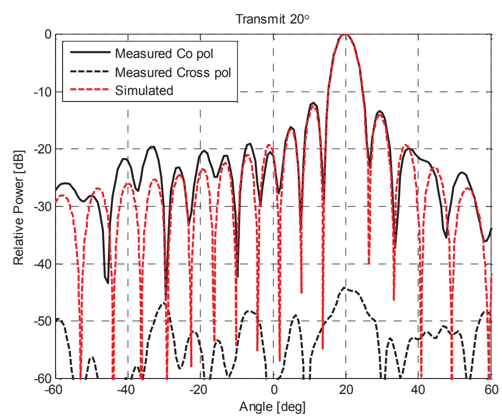

Figure 8: Antenna transmit patterns for 20^o steering angle.

V. CONCLUSION AND FUTURE WORK

We developed techniques compatible with construction of multi-layer large active membrane arrays. These techniques include alignment, seaming and routing of RF signals to build a large array using smaller panels. We also developed miniaturized membrane-compatible T/R modules. We demonstrated a 16x16 element active array to evaluate the manufacturing techniques discussed above and the array design.

To further develop membrane-based phased array technology we need to address the deployment of the antenna. As part of this work we developed a new deployment concept which is ready for implementation when future technology development opportunities become available. In this paper we also discussed the need for an integrated divider instead of the 16 way divider shown in Figure 2. Since the completion of this task there have been advances in flexible circuit fabrication that will allow the integration of the divider with the rest of the array.

VI. ACKNOWLEDGMENTS

This work was performed at Jet Propulsion Laboratory under contract with the National Aeronautics and Space Administration.

REFERENCES

[1] JPL 400-1069, "Global Earthquake Satellite System GESS: A 20 year plan to enable earthquake prediction," March 2003

[2] S.N. Madsen, W. Edelstein, L.D. DiDomenico, J. LaBrecque, "A geosynchronous synthetic aperture radar; for tectonic mapping, disaster management and measurements of vegetation and soil moisture," *IEEE Symposium on Geoscience and Remote Sensing, IGARSS'01*, pp. 447-449, 2001.

[3] S.N. Madsen, C. Chen, and W. Edelstein, "Radar Options for Global Earthquake Monitoring," *IEEE Symposium on Geoscience and Remote Sensing, IGARSS'02*, July, 2002.

[4] Curtis Chen, Alina Moussessian, "MEO SAR System Concepts and Technologies for Earth Remote Sensing," *AIAA,* September 2004.

[5] Alina Moussessian, Curtis Chen, Wendy Edelstein, Soren Madsen, Paul Rosen, "System Concepts and Technologies for High Orbit SAR," *The IEEE MTT-S International Microwave Symposium, Long Beach, CA, June 2005.*

[6] Huang, Lou, Feria and Kim " An Inflatable L-band Microstrip SAR Aray," *IEEE AP-S/URSI Symposium,* Atlanta, GA, June 1998, pp. 2100-2103

[7] A. Moussessian, L. Del Castillo, J. Huang, G. Sadowy, J. Hoffman, P. Smith, T. Hatake, C. Derksen, B. Lopez, " A Membrane Array Using T/R Membranes," *Earth-Sun System Technology Conference*, June 2005.

[8] A. Moussessian, L. Del Castillo, M. Zawadzki, U. Quijano, V. Bach, E. Weininger, J. Hoffman, P. Rosen, "An Electronically Scanned Large Aperture Membrane Array," *NASA Space Technology Conference,* June 2007.

[9] J. Huang, A. Moussessian, "Thin membrane Aperture-Coupled L-Band Patch Antenna," *APS*, June 2004.